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Mikami

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(54) **ANTENNA INTEGRATED WITH SOLAR BATTERY**

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(51) **Int. Cl.**

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H01Q 1/36	(2006.01)
H01Q 1/22	(2006.01)
H01Q 1/44	(2006.01)
H01Q 9/04	(2006.01)
H01Q 9/28	(2006.01)

(52) **U.S. Cl.**

CPC . ***H01Q 1/36*** (2013.01); ***H01Q 1/22*** (2013.01); ***H01Q 1/44*** (2013.01); ***H01Q 9/0407*** (2013.01); ***H01Q 9/285*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/36; H01Q 1/22; H01Q 1/44; H01Q 9/285; H01Q 9/0407

USPC .... 343/897, 700 MS

See application file for complete search history.

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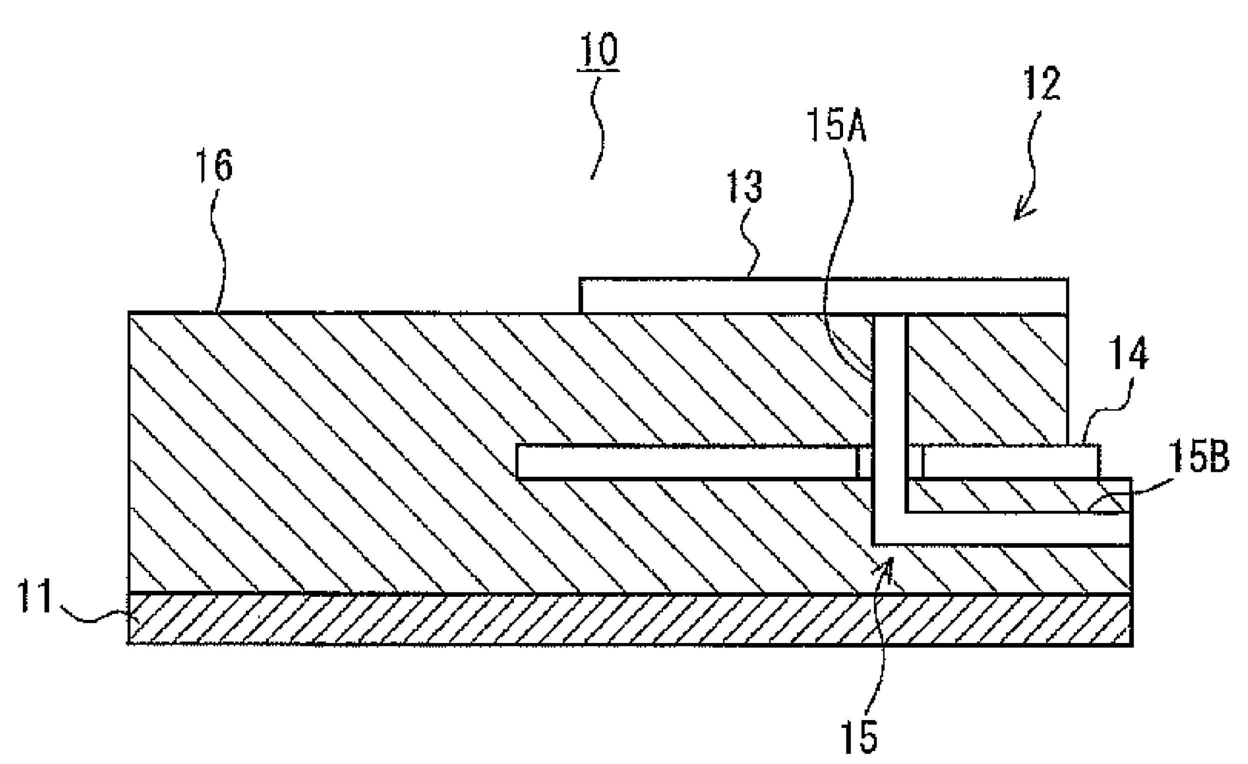
(57) **ABSTRACT**

An antenna is integrated with a solar battery. The antenna has a radiation-element portion arranged above the solar battery. The radiation-element portion is made of metallic wire rods and formed in a net-like fashion.

9 Claims, 9 Drawing Sheets



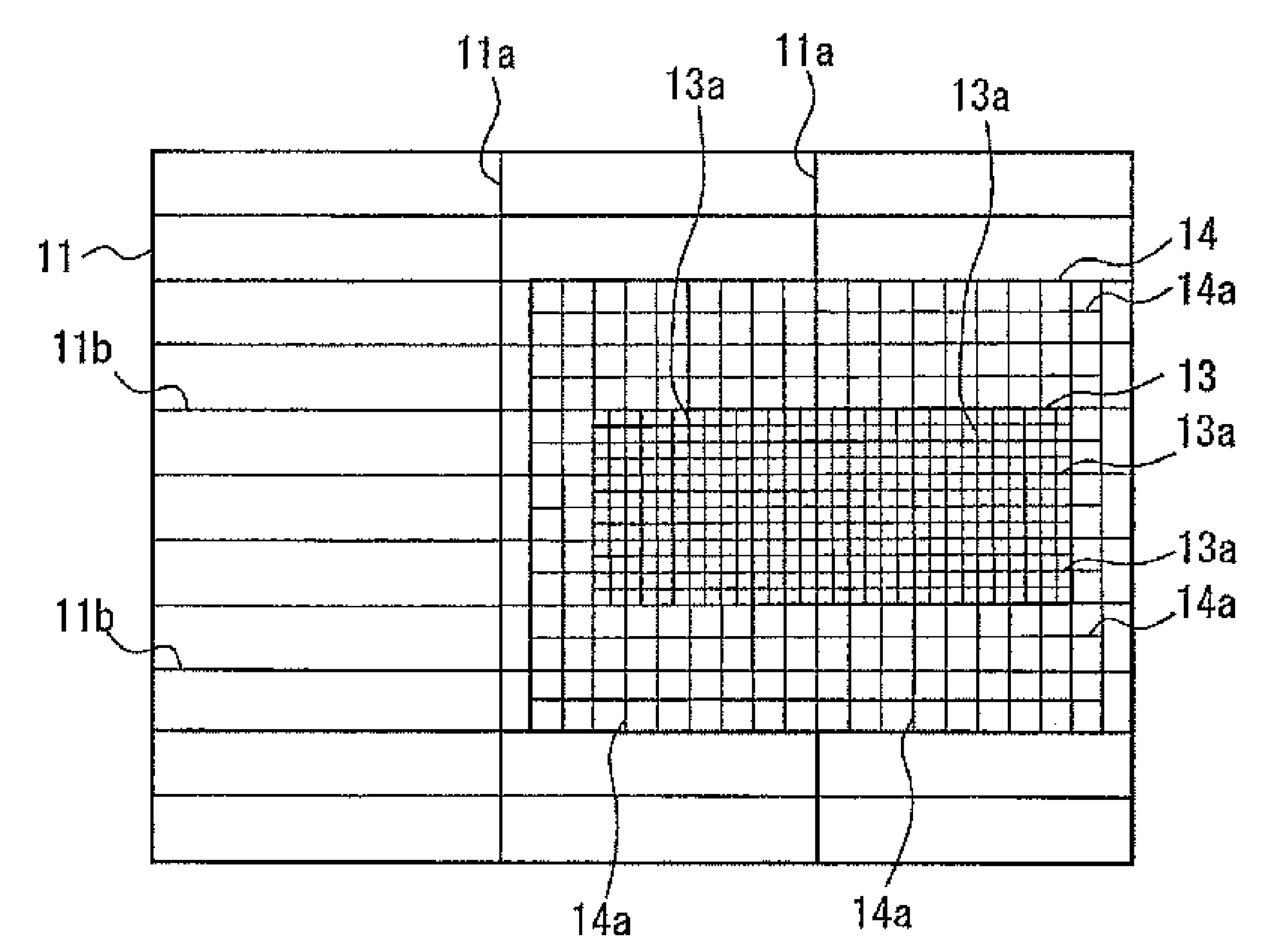


FIG. 1A

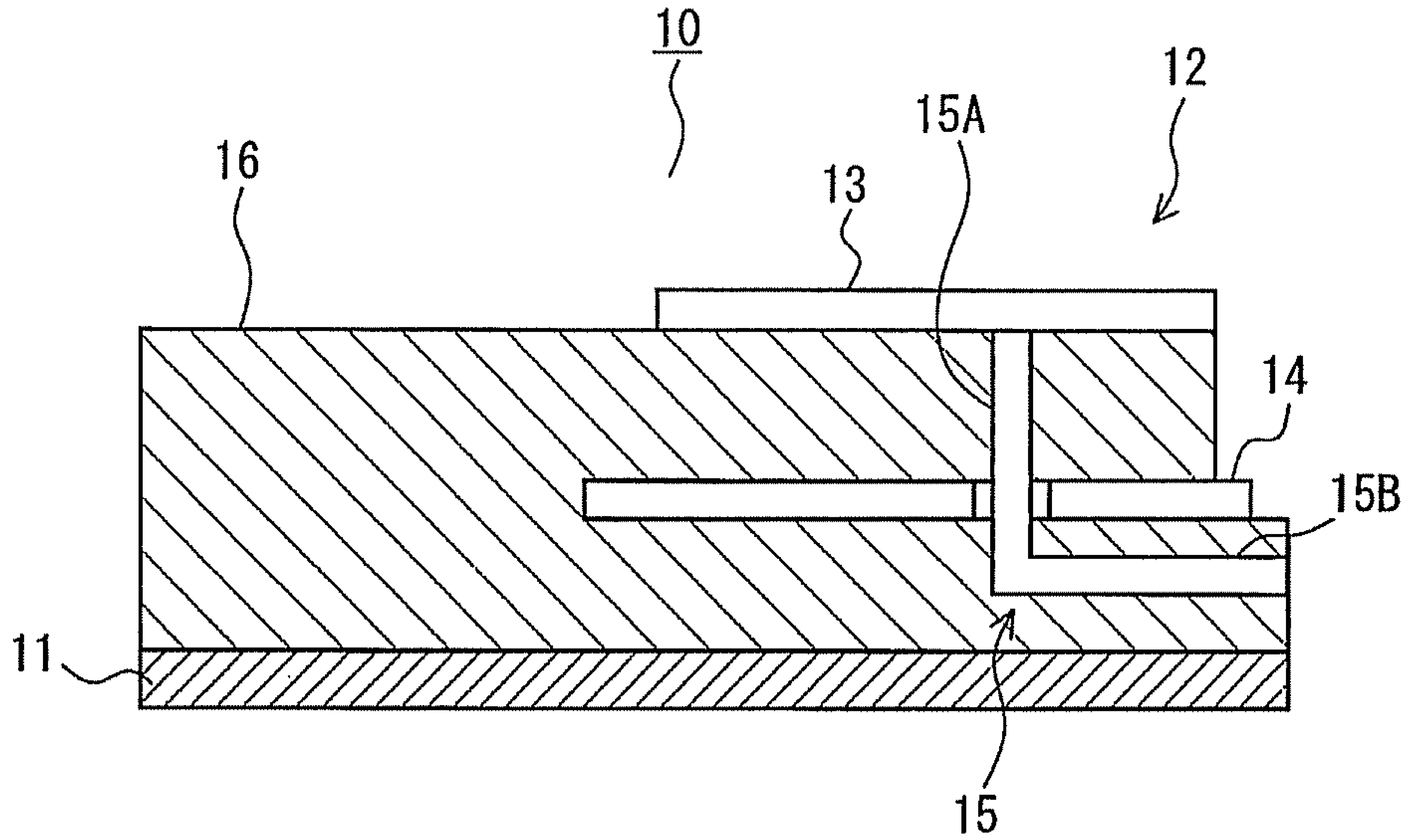
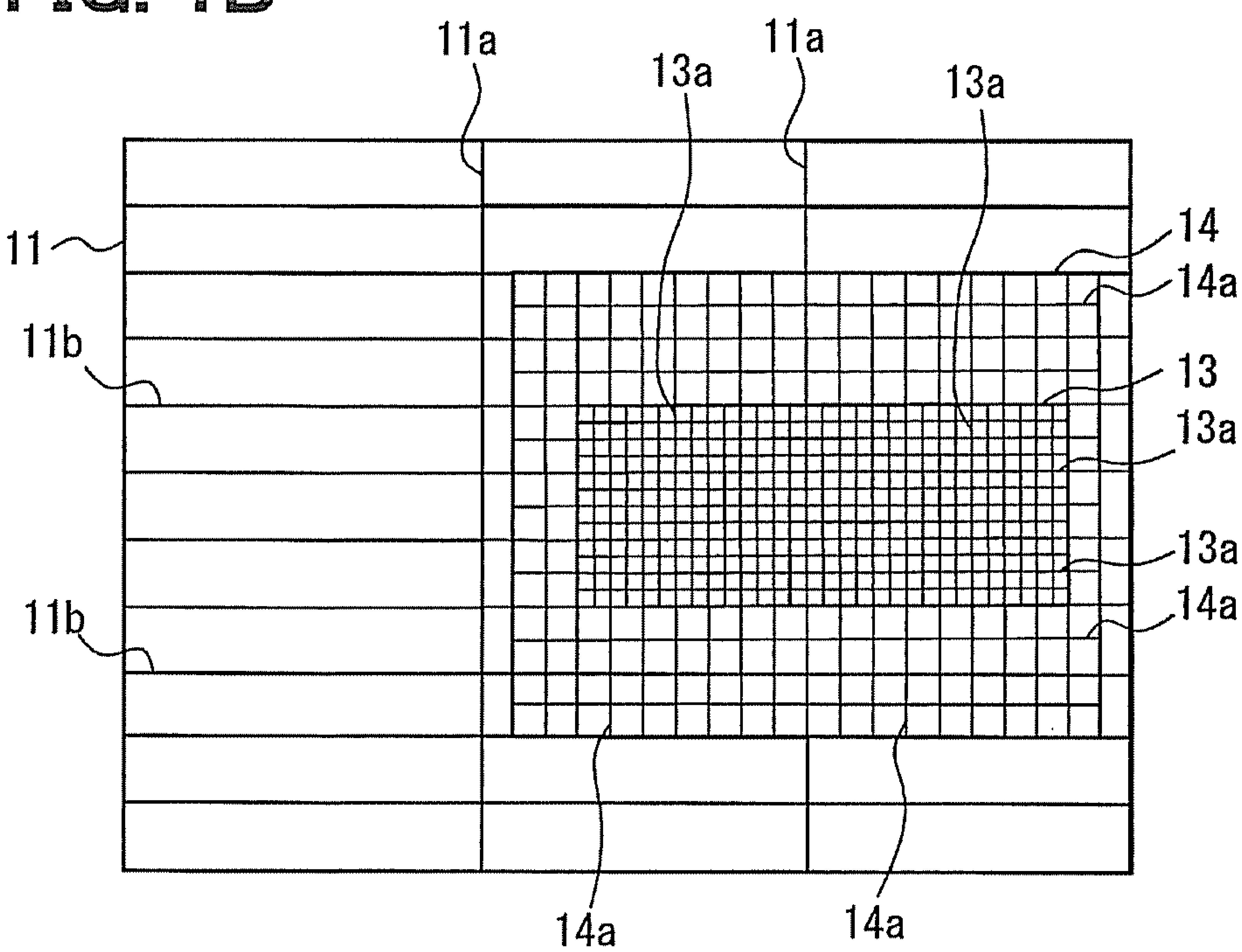

10
12
16
15A
13
14
15B
11
15

FIG. 1B


11a
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11
14
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11b
13
13a
13a
11b
14a
14a
14a

FIG. 2

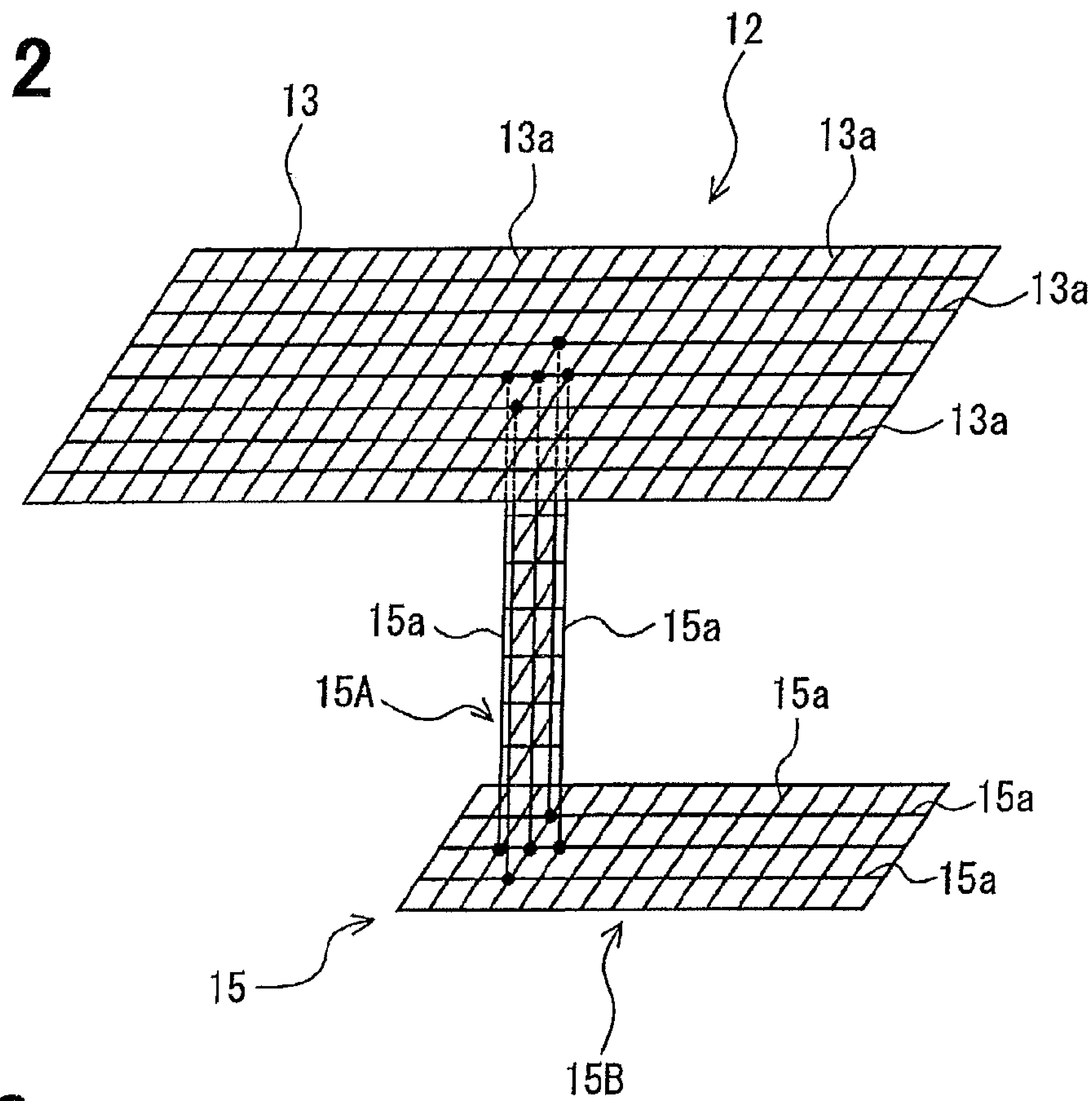


FIG. 3

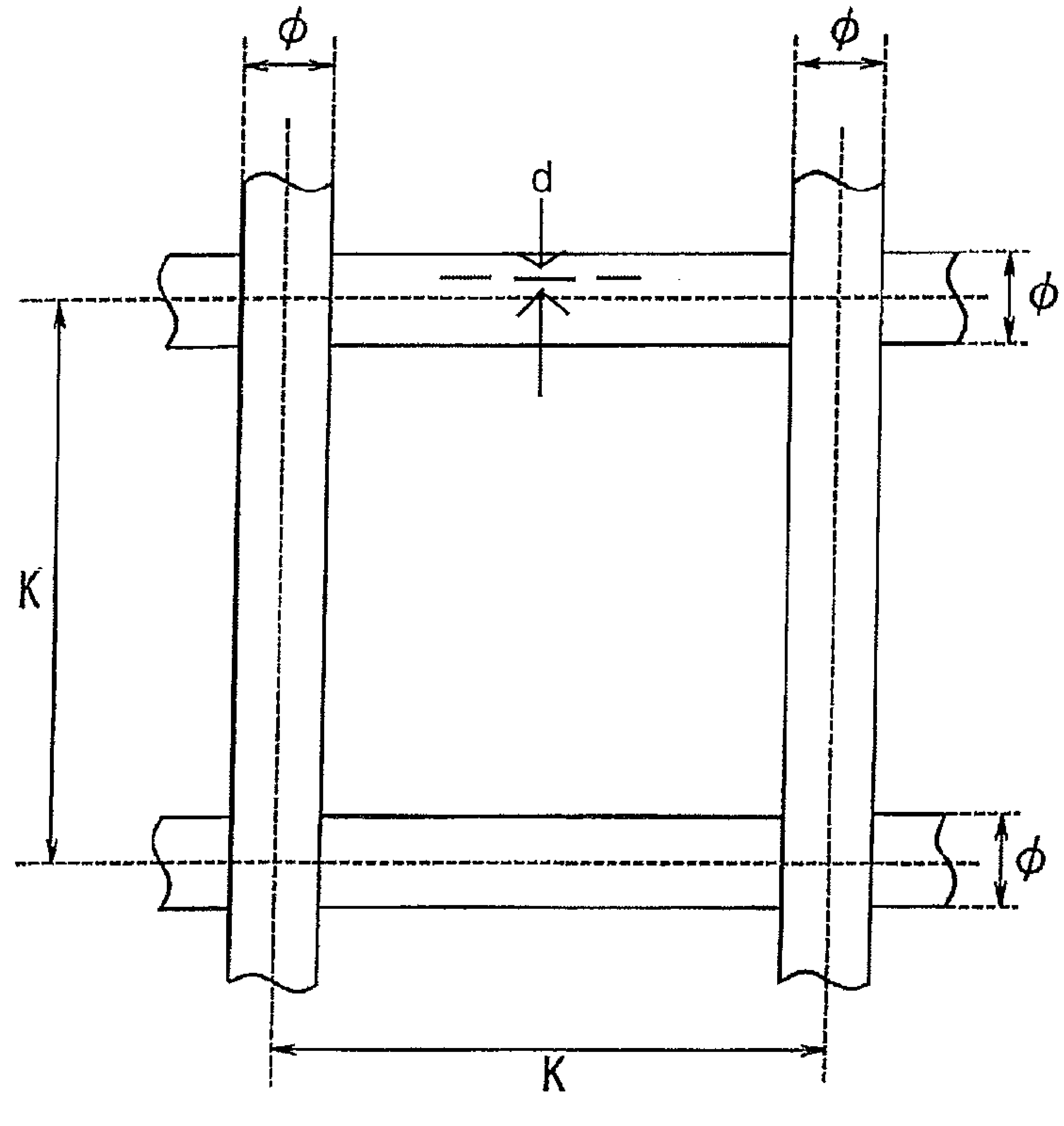


FIG. 4A

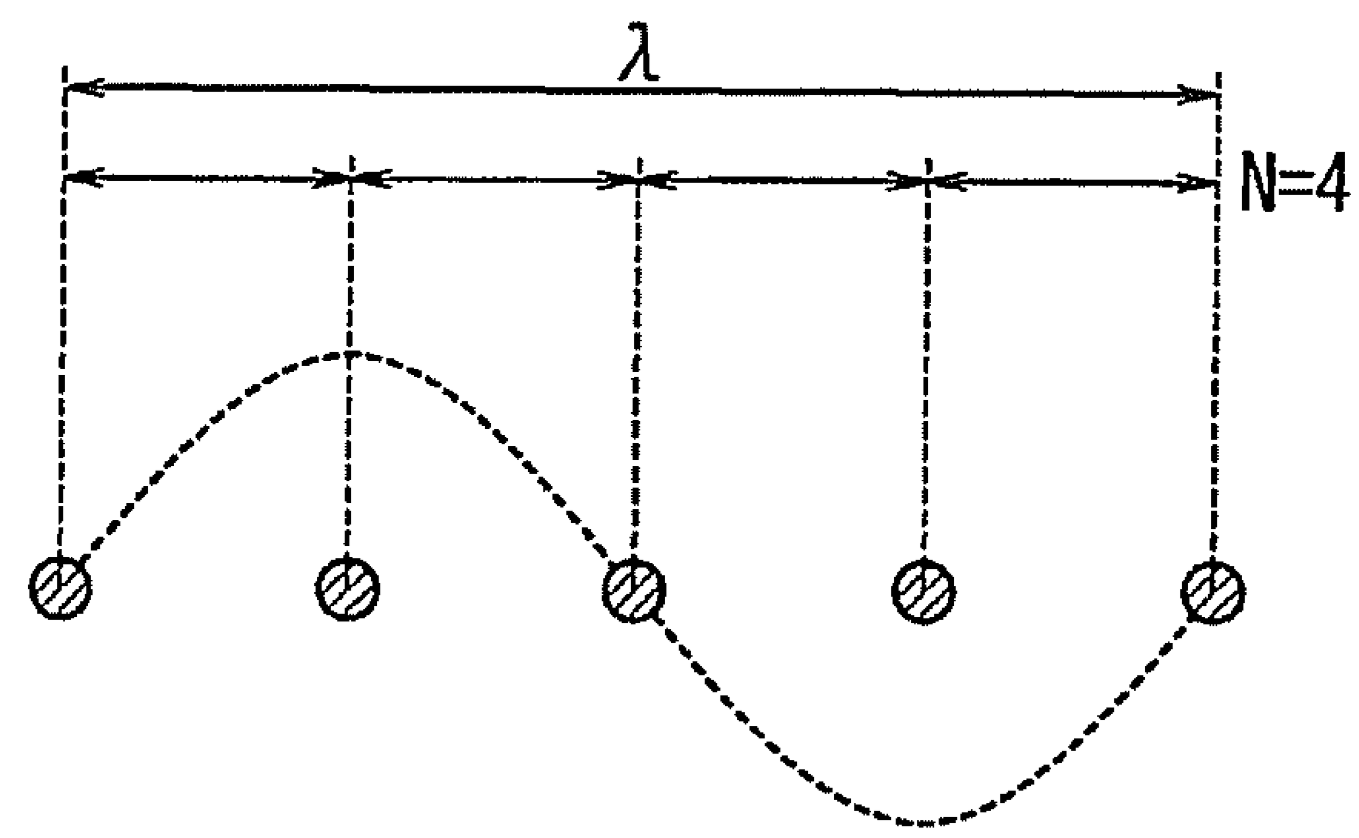


FIG. 4B

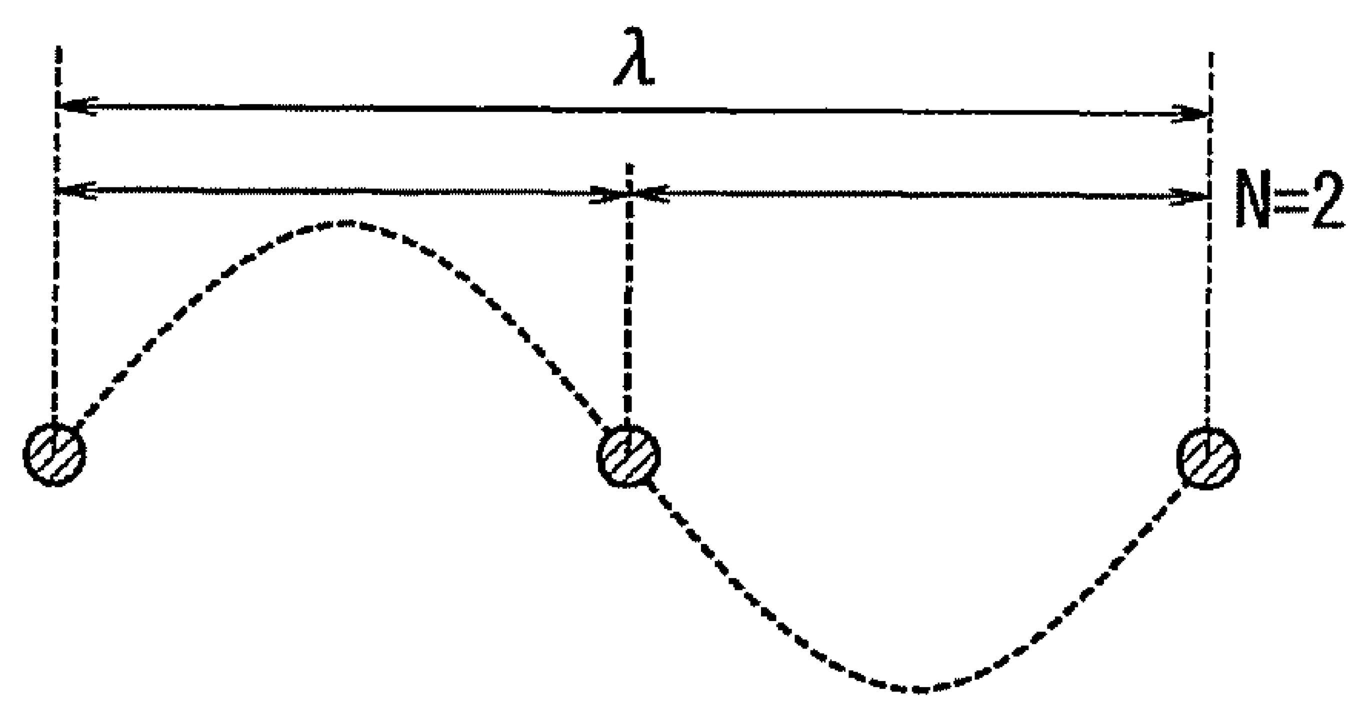


FIG. 4C

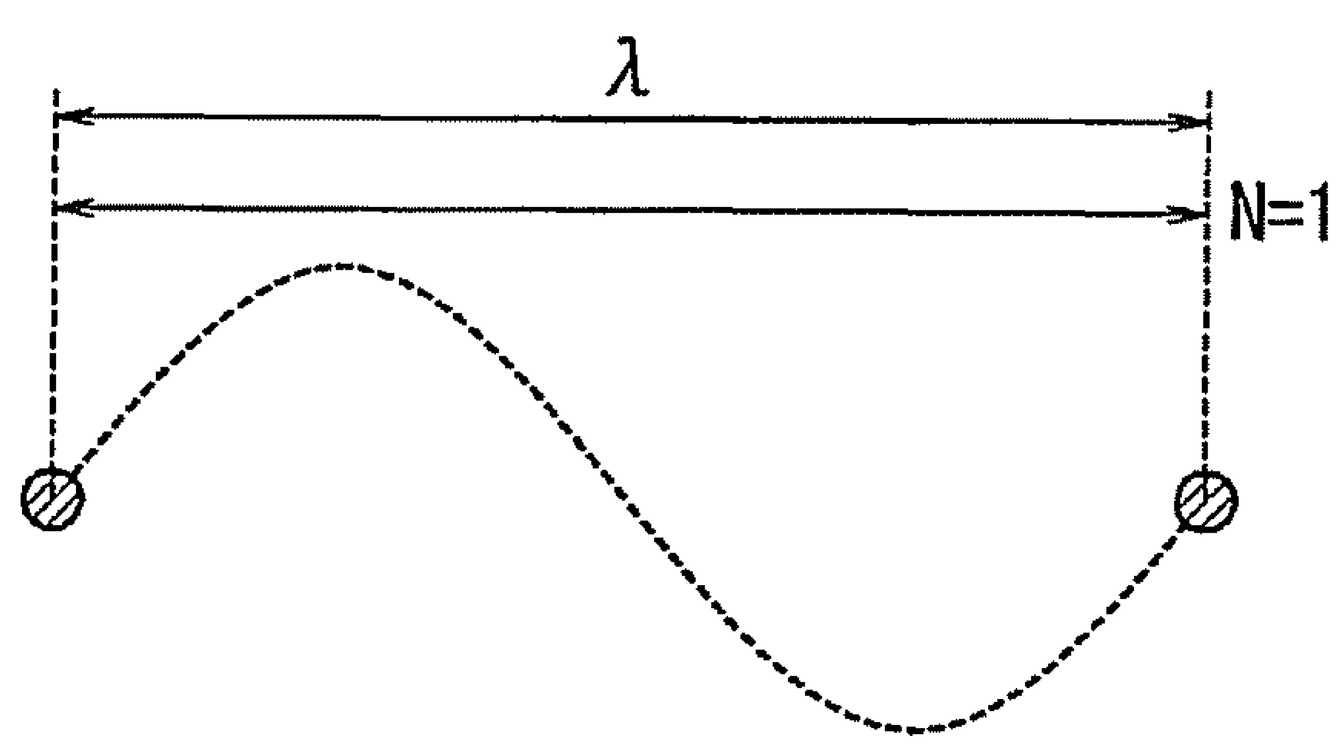


FIG. 5

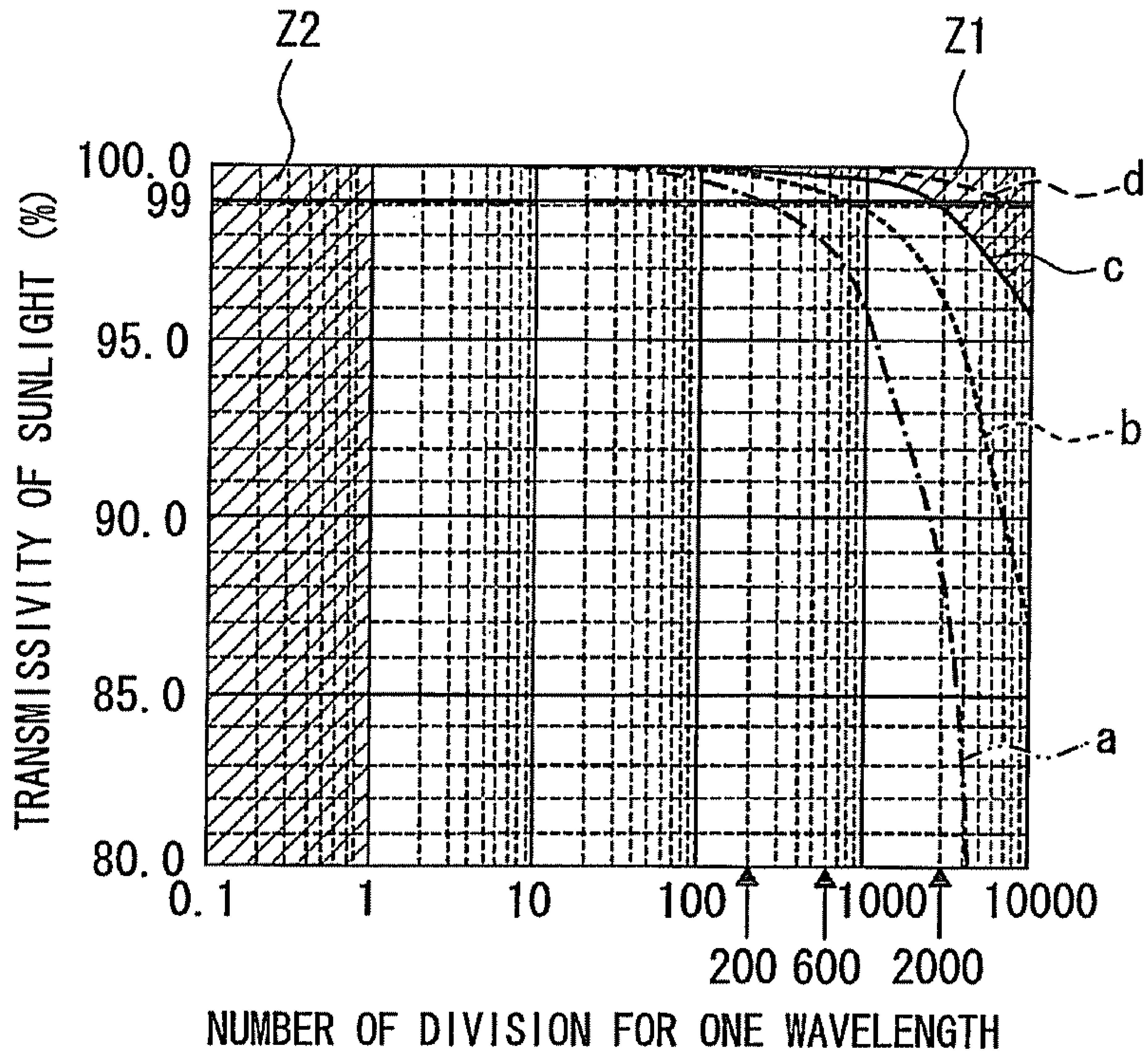

Z2
Z1
100.0
99
95.0
90.0
85.0
80.0
TRANSMISSIVITY OF SUNLIGHT (%)
d
c
b
a
0.1
1
10
100
1000
10000
200 600 2000
NUMBER OF DIVISION FOR ONE WAVELENGTH

FIG. 6A

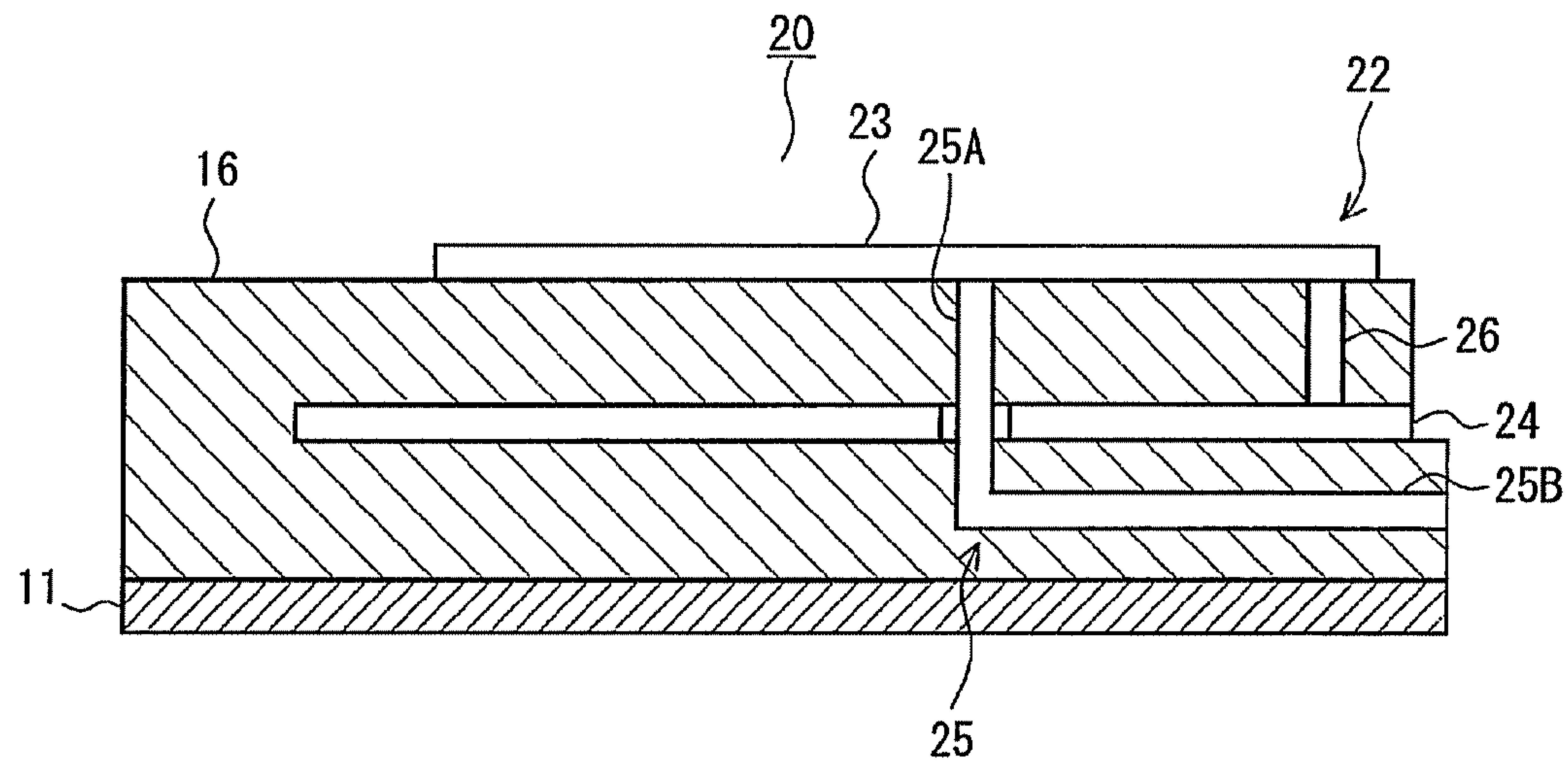

20
23
25A
22
16
26
24
25B
11
25

FIG. 6B

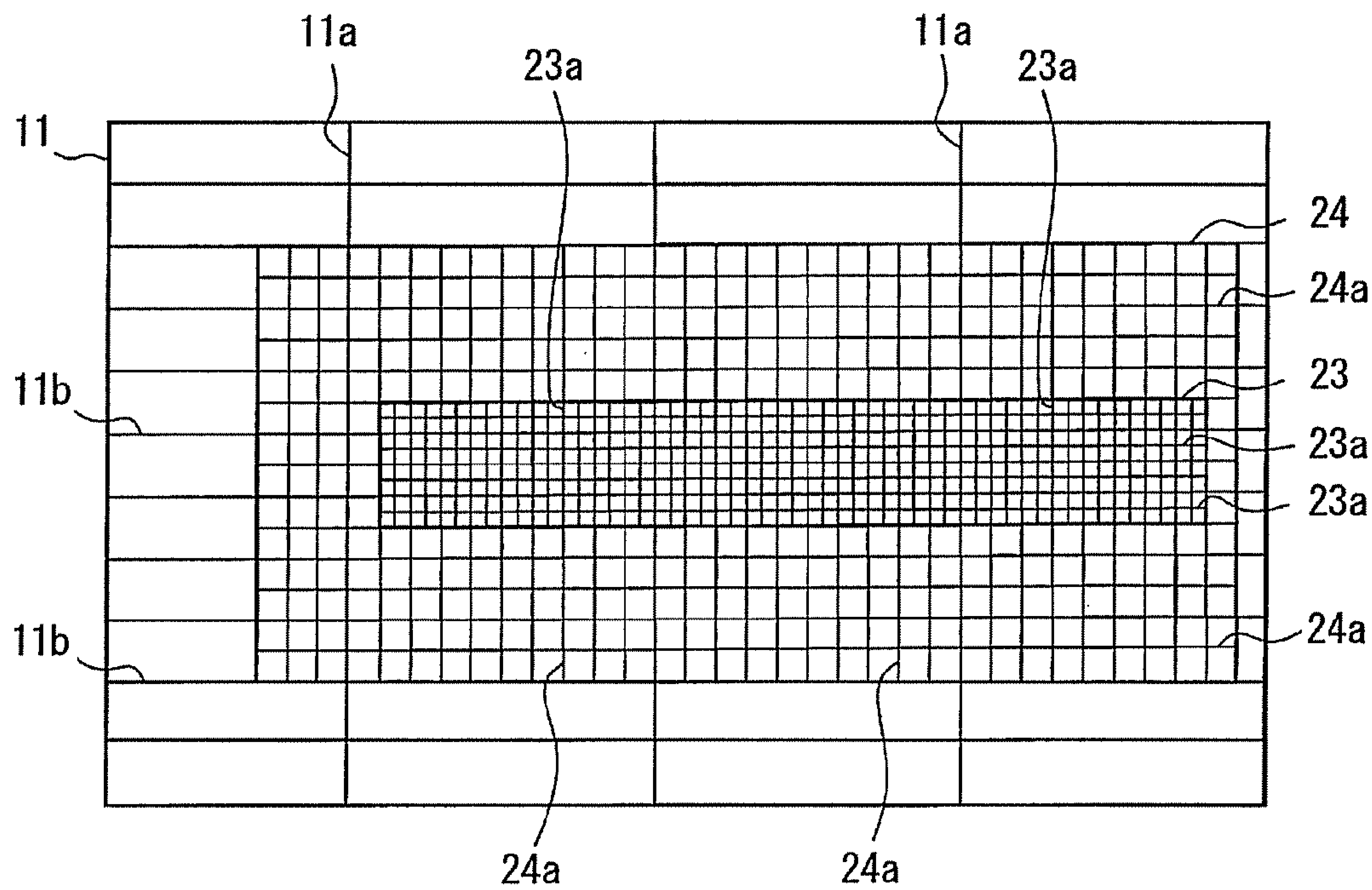

11a
11a
23a
23a
11
24
24a
23
11b
23a
23a
11b
24a
24a
24a

FIG. 7A

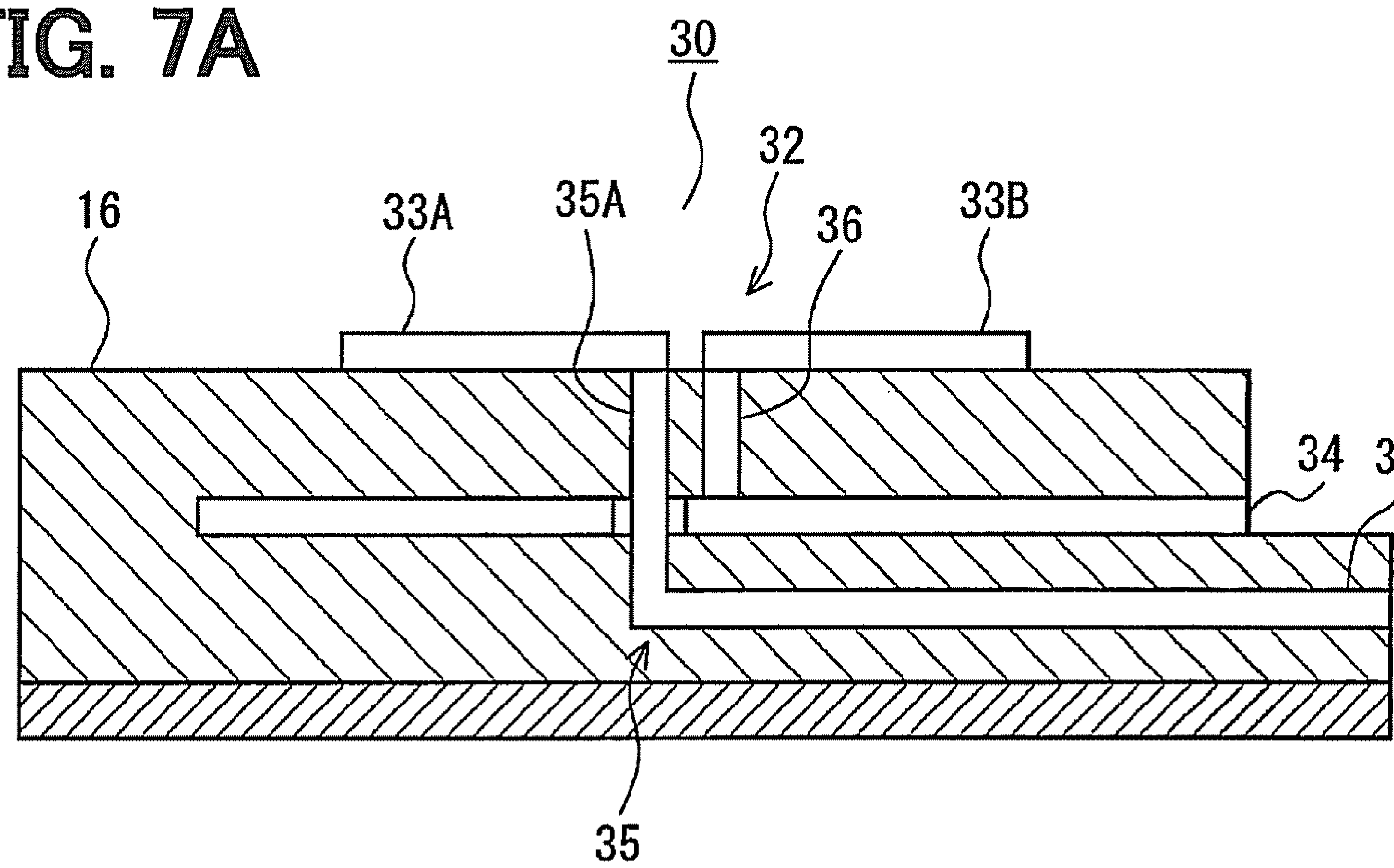

30
32
16
33A
35A
36
33B
34
35B
35

FIG. 7B

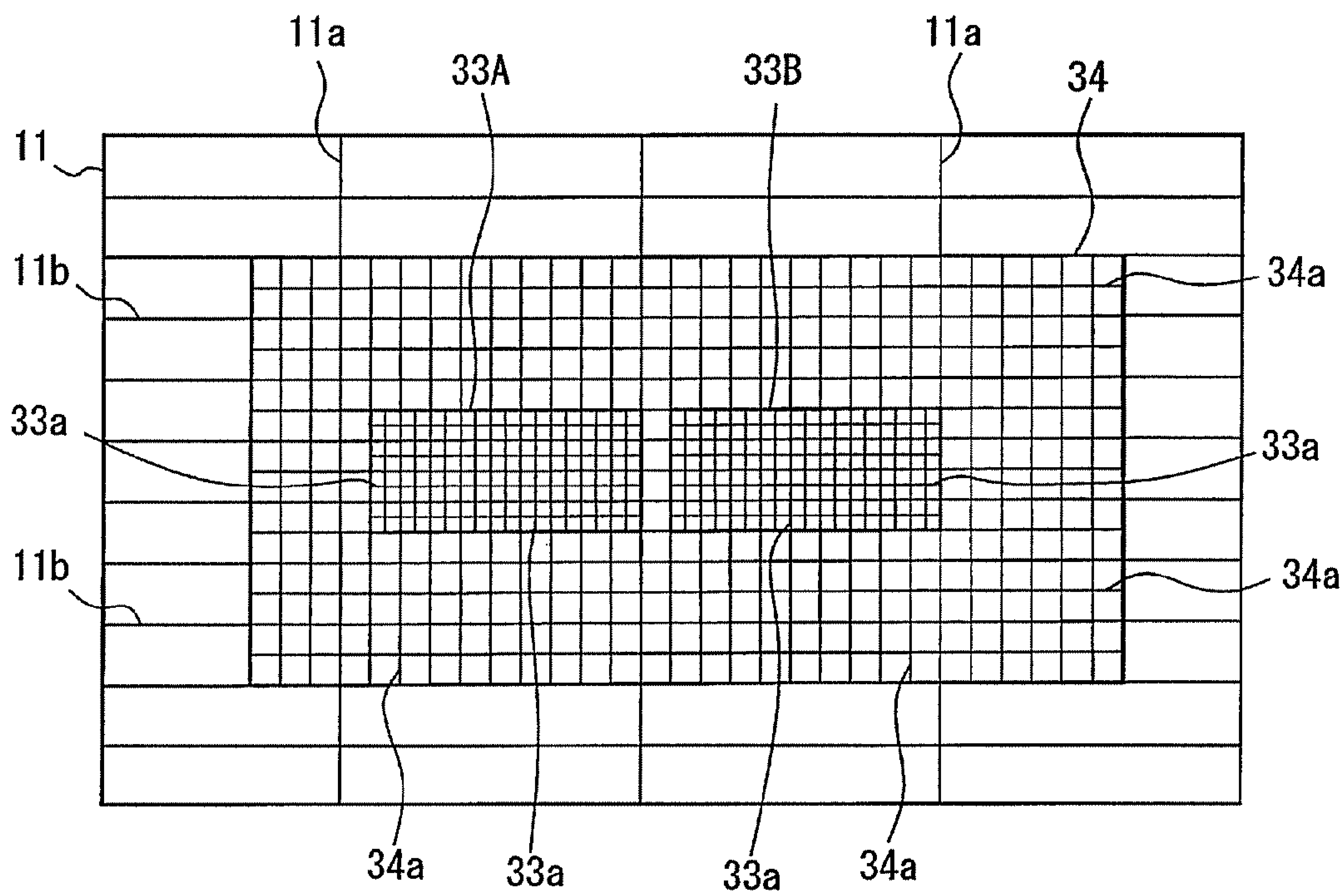

11a
33A
33B
11a
34
11
11b
34a
33a
33a
11b
34a
34a
33a
33a
34a

FIG. 8A

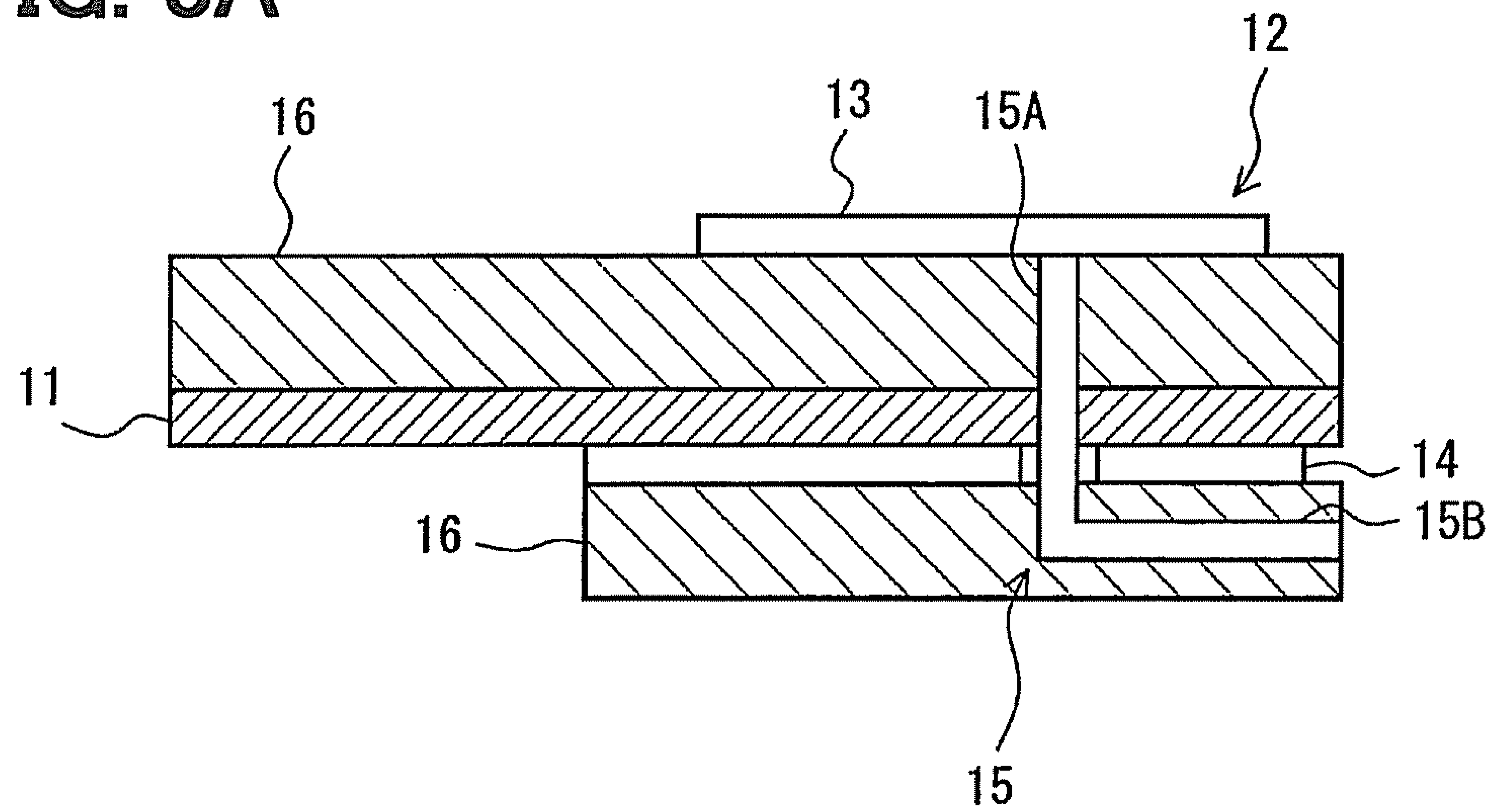


FIG. 8B

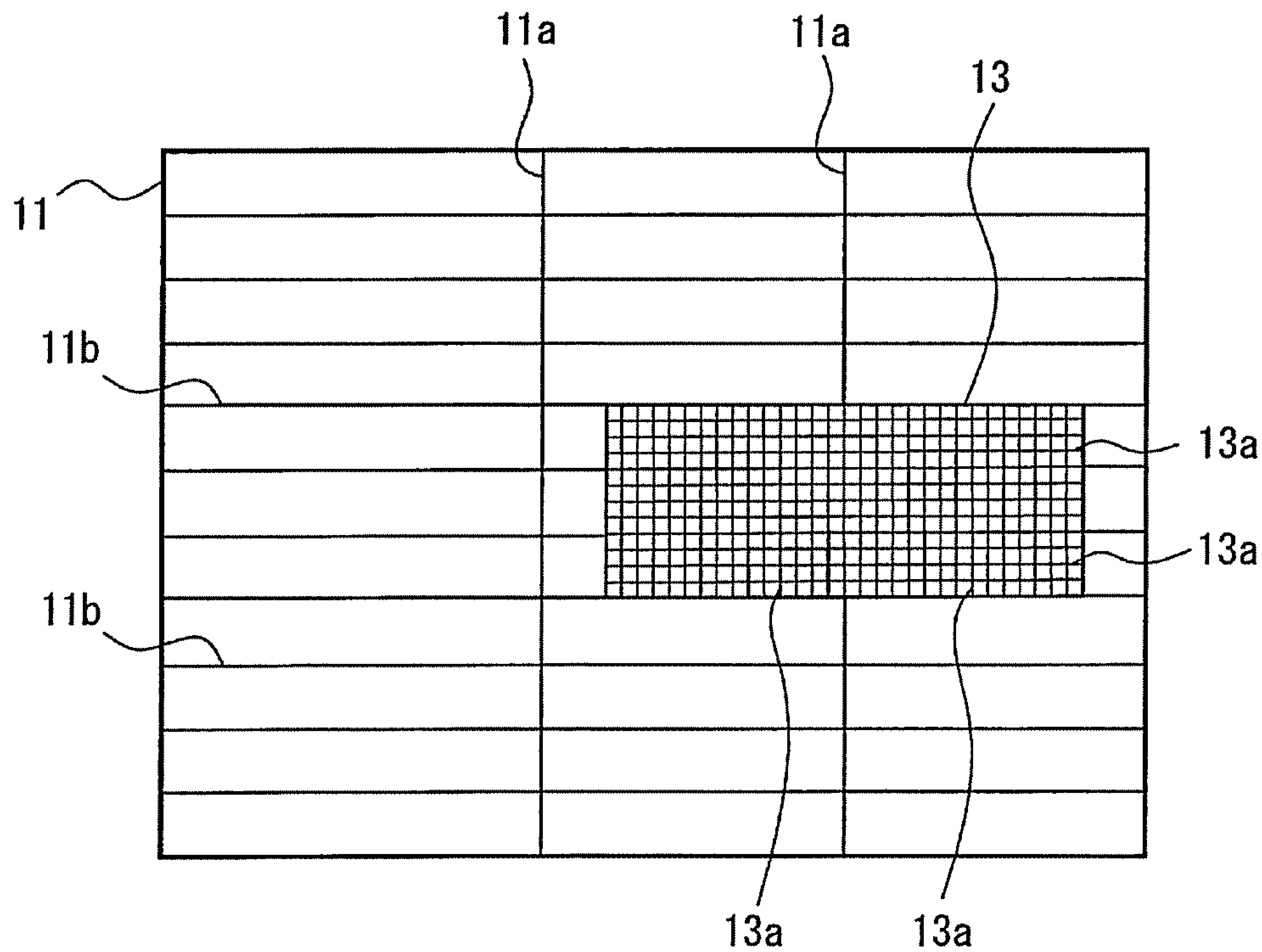


FIG. 9A

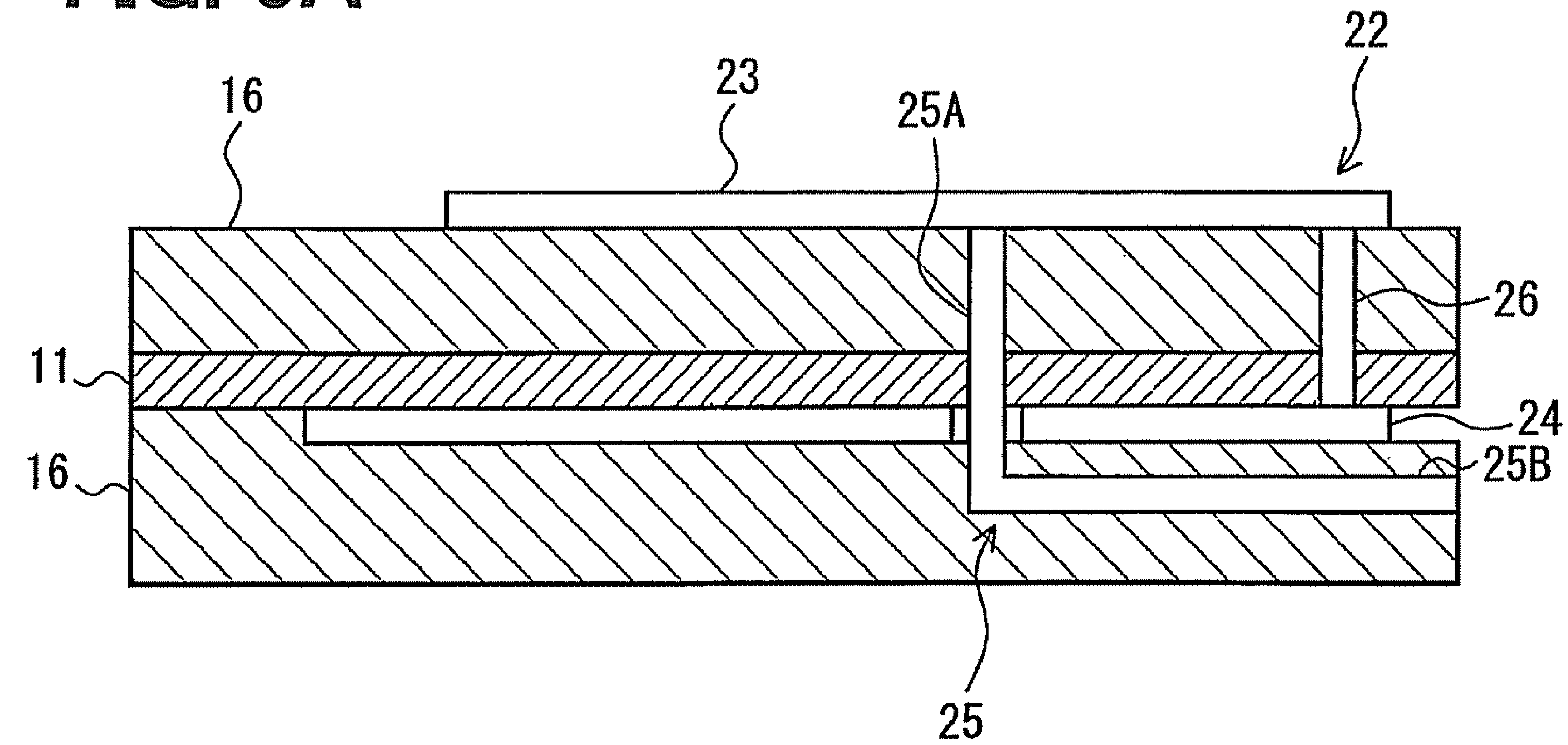

22
23
25A
16
26
11
24
16
25B
25

FIG. 9B

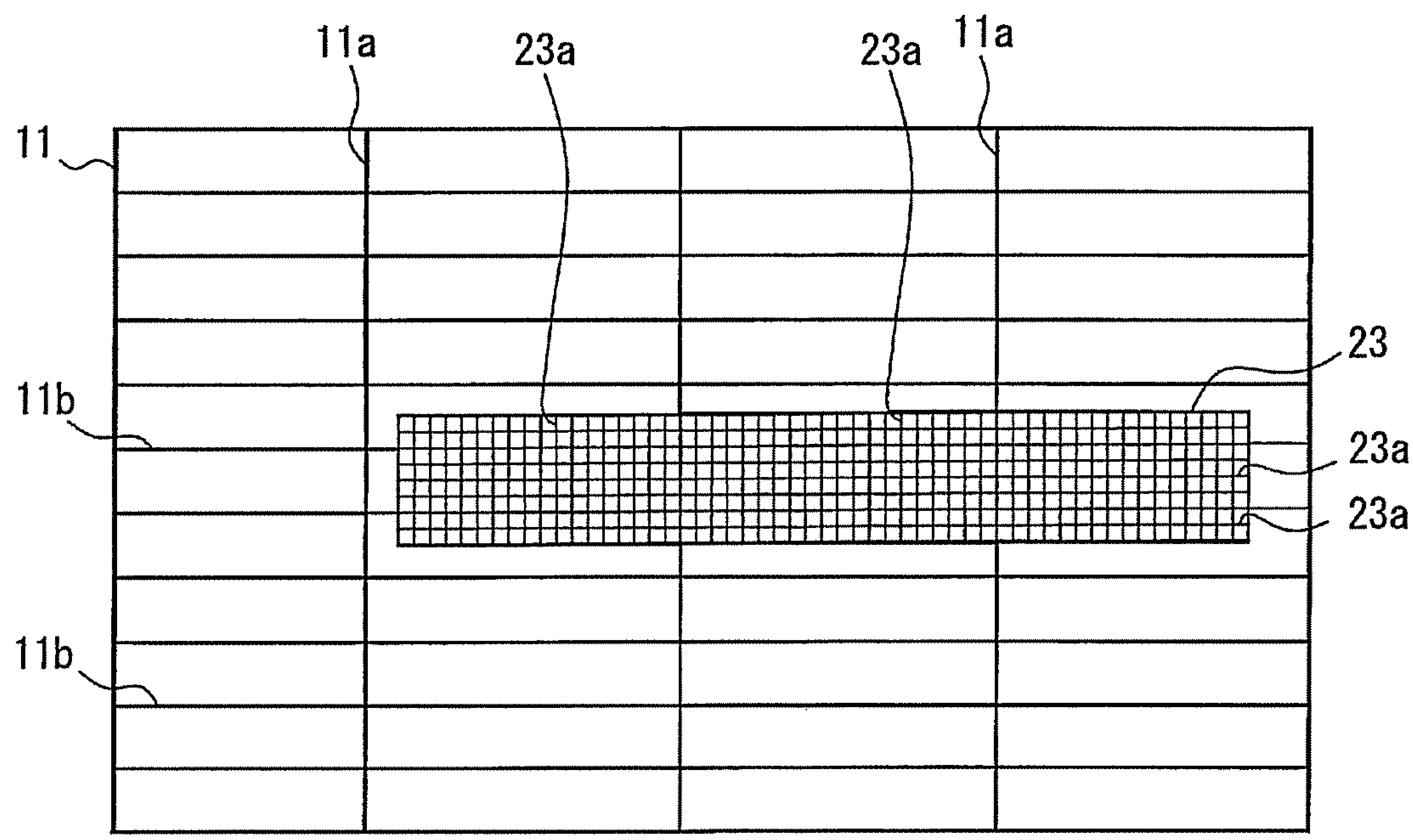

11a
23a
23a
11a
11
23
11b
23a
23a
11b

FIG. 10A

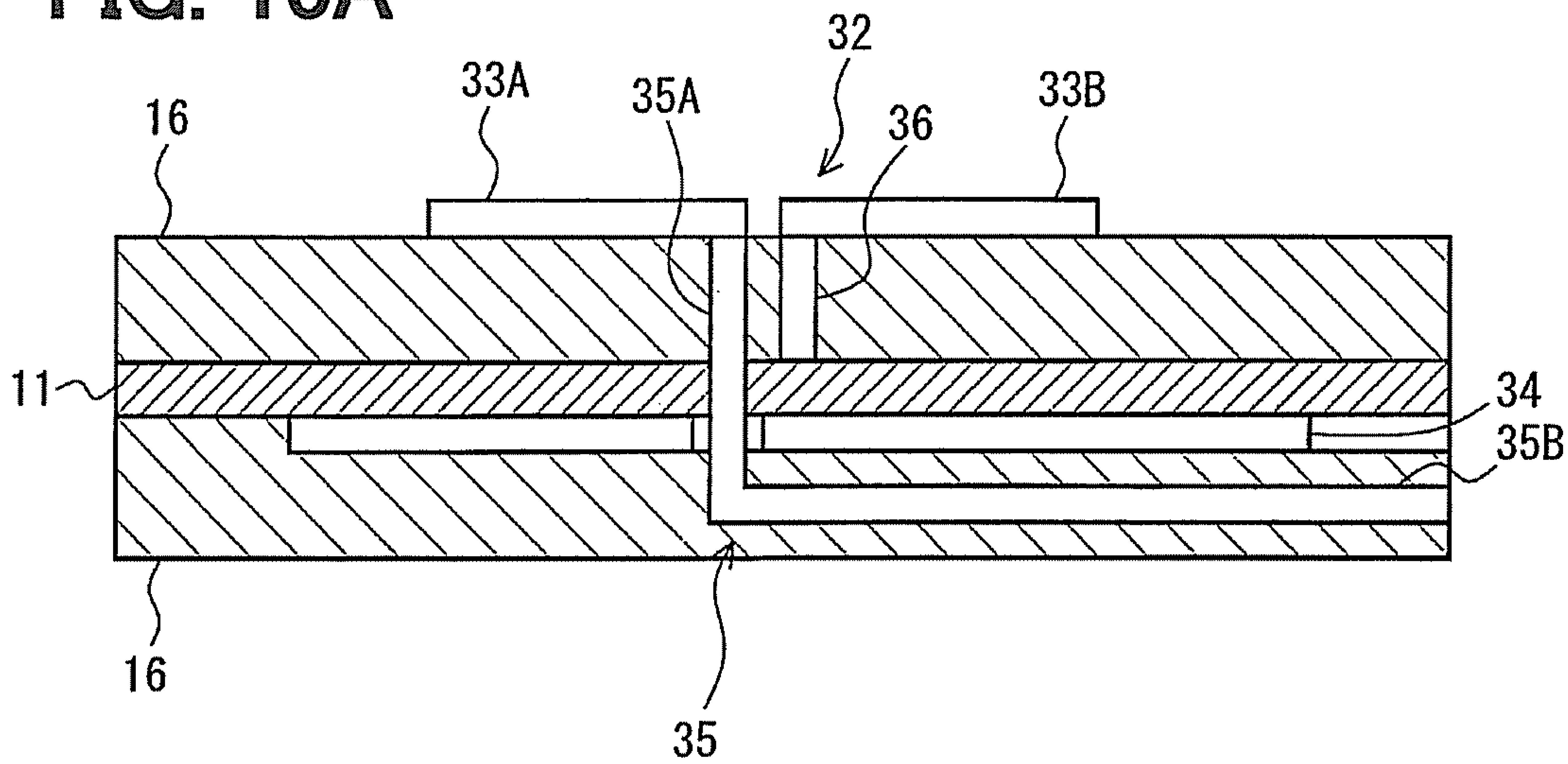
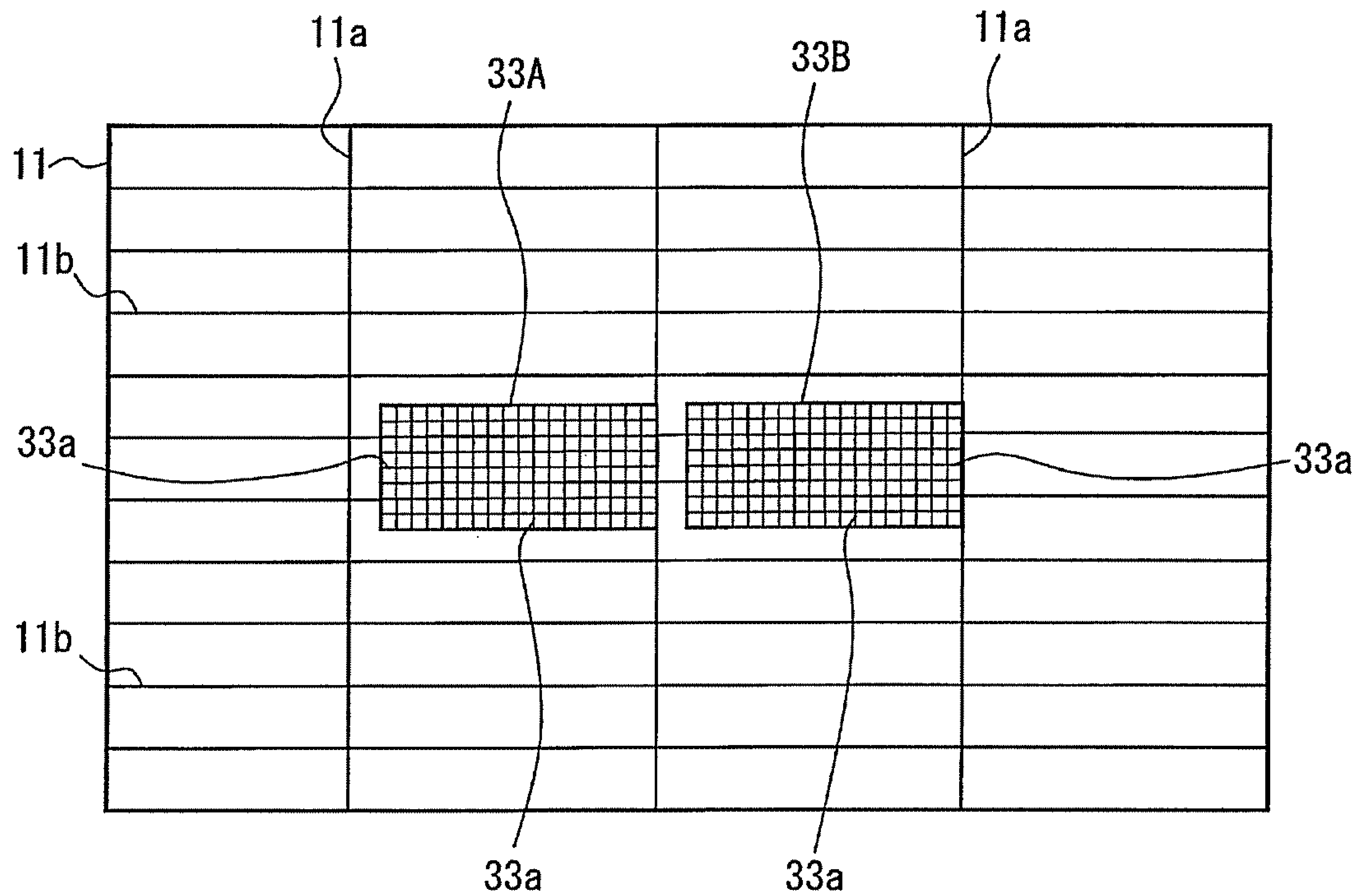


FIG. 10B



ANTENNA INTEGRATED WITH SOLAR BATTERY

CROSS REFERENCE TO RELATED APPLICATION

This application is based on Japanese Patent Application No. 2012-021804 filed on Feb. 3, 2012, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to an antenna integrated with a solar battery.

BACKGROUND

An antenna integrated with a solar battery is known in the art, for example, as disclosed in Japanese Patent Publication No. H10-270925. The prior art antenna, which is composed of an electric-conductor film and an array-antenna element, is formed on a solar battery. The electric-conductor film of the antenna is made of metallic material, which is formed in a thin film. Since resistivity of the electric-conductor film is high, loss of the antenna as a whole is large. Antenna gain is thereby largely decreased.

SUMMARY OF THE DISCLOSURE

The present disclosure is made in view of the above points. It is an object of the present disclosure to provide an antenna integrated with a solar battery, according to which loss of the antenna can be reduced as a whole so as to improve antenna gain.

According to a feature of the present disclosure, an antenna integrated with a solar battery is composed of the solar battery and an antenna, wherein the antenna has a radiation-element portion above the solar battery. The radiation-element portion is made of metallic material and formed not in a thin film but in a net-like fashion. Resistivity of such radiation-element portion is not increased and loss of antenna can be made smaller as a whole. Accordingly, antenna gain is improved.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1**A is a schematic cross sectional view showing a structure of an antenna integrated with a solar battery according to a first embodiment of the present disclosure;

FIG. **1**B is a schematic plane view showing the antenna integrated with the solar battery, in which a dielectric body is omitted from the drawing;

FIG. **2** is a schematic perspective view showing the structure of the antenna;

FIG. **3** is an enlarged schematic view showing a relevant portion of the antenna, in which wire rods cross with each other;

FIGS. **4**A to **4**C are schematic views for explaining relationship between a number of the wire rods included in one wavelength and a number of division for one wavelength;

FIG. **5** is a graph showing relationship between the number of division for one wavelength and transmissivity of sunlight with respect to the antenna;

FIGS. **6**A and **6**B are a cross sectional view and a plane view, each schematically showing an antenna integrated with a solar battery according to a second embodiment of the present disclosure;

FIGS. **7**A and **7**B are a cross sectional view and a plane view, each schematically showing an antenna integrated with a solar battery according to a third embodiment of the present disclosure;

FIGS. **8**A and **8**B are a cross sectional view and a plane view, each schematically showing a modification of the first embodiment;

FIGS. **9**A and **9**B are a cross sectional view and a plane view, each schematically showing a modification of the second embodiment; and

FIGS. **10**A and **10**B are a cross sectional view and a plane view, each schematically showing a modification of the third embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

(First Embodiment)

A first embodiment of the present disclosure will be explained with reference to FIGS. **1** to **5**. A structure of an antenna, which is formed in a flat shape (so-called, a patch antenna), will be explained.

As shown in FIG. **1**A, an antenna **10** integrated with a solar battery is composed of a solar battery **11** and a patch antenna **12**.

As shown in FIG. **1**B, the solar battery **11** is formed in a rectangular shape, one of surfaces of which is directed in an upward direction. The solar battery **11** is composed of multiple bus-bar electrodes **11***a* and multiple grid lines **11***b* crossing with the bus-bar electrodes **11***a* at a right angle. In the solar battery **11**, a power-generation cell receives sunlight to generate electric power, which is collected at the bus-bar electrodes **11***a* via the respective grid lines **11***b* and charged in a battery.

The patch antenna **12** has a radiation-element portion **13** arranged on an upper side of the solar battery **11**. As shown in FIG. **1**B and FIG. **2**, the radiation-element portion **13** is made of fine metallic wire rods **13***a* and formed in a net-like fashion. The patch antenna **12** has a bottom-board portion **14** arranged above the solar battery **11**. The bottom-board portion **14** is likewise made of fine metallic wire rods **14***a* and formed in a net-like fashion. The patch antenna **12** further has a feed-line portion **15** arranged above the solar battery **11** but below the bottom-board portion **14**. As shown in FIG. **2**, the feed-line portion **15** is likewise made of fine metallic wire rods **15***a* and formed in a net-like fashion. The feed-line portion **15** is composed of a vertical feed-line portion **15**A extending in a vertical direction and a horizontal feed-line portion **15**B extending in a horizontal direction.

The wire rods **13***a*, **14***a* and **15***a* of the radiation-element portion **13**, the bottom-board portion **14** and the feed-line portion **15** overlap each other in the vertical direction. Furthermore, the wire rods **13***a*, **14***a* and **15***a* are arranged to overlap the bus-bar electrodes **11***a* and grid lines **11***b* in the vertical direction. The radiation-element portion **13**, the bottom-board portion **14** and the feed-line portion **15** are supported by a transparent dielectric body **16**. The dielectric body **16** is made of, for example, glass-based material or resin-based material. The dielectric body **16** has a rectangular outer shape, when viewed in the vertical direction. The outer shape of the dielectric body **16** coincides with the rectangular outer shape of the solar battery **11** in the vertical direction.

As shown in FIG. **2**, each of the wire rods **15***a* of the vertical feed-line portion **15**A is connected to respective wire rods **13***a* of the radiation-element portion **13**, at each connecting point between the radiation-element portion **13** and the vertical feed-line portion **15**A. In a similar manner, each of the wire rods **15***a* of the vertical feed-line portion **15**A is connected to respective wire rods **15***a* of the horizontal feed-line portion **1513**, at each connecting point between the vertical feed-line portion **15**A and the horizontal feed-line portion **15**B. Multiple wire rods **15***a* of the vertical feed-line portion **15**A are arranged in a crosswise form, when viewed in the vertical direction.

A wire diameter "ϕ" (shown in FIG. **3**) of each wire rod **13***a*, **14***a* and **15***a* is made to be larger than an epidermal depth "d" of each wire rod **13***a*, **14***a*, and **15***a* at a usable frequency for the patch antenna **12**. The epidermal depth "d [m]" can be obtained by the following formula 1:

$$d=\sqrt{(2/\omega\cdot\mu\cdot\rho)} \qquad \text{<Formula 1>}$$

ω: 2 π f

f: usable frequency [Hz] for the antenna

μ: magnetic permeability [H/m]

ρ: electric conductivity [S/m]

For example, in a case that the usable frequency "f" for the antenna is "100×10^6 [Hz]", the magnetic permeability "μ" of the wire rod is "$4\pi\times10^{-7}$ [H/m]", and the electric conductivity "ρ" of the wire rod (cupper) is "58×10^6 [S/m]", then the epidermal depth becomes "6.6×10^{-6} [m]".

Each of intervals "K" (shown in FIG. **3**) between the respective wire rods **13***a*, **14***a* and **15***a* is decided so as to meet the following formula 2:

$$K=\lambda/N \qquad \text{<Formula 2>}$$

λ: wavelength [m] obtained from the usable frequency for the antenna,

N: a number of division for one wavelength

As above, each of the respective intervals "K" is set as a value smaller than the wavelength "λ" obtained from the usable frequency of the antenna.

The number "N" of division for one wavelength indicates a number of divided parts of the waveform for one wavelength, wherein one wavelength "λ" is divided into several parts by multiple wire rods included in a range of one wavelength. In other words, the number "N" of division for one wavelength is related to a number of wire rods included in the range of the one wavelength.

For example, as shown in FIG. **4**A, when the number of the wire rods is 5 (five) included in one wavelength, the number "N" of division becomes 4 (four). In a case that the number of the wire rods is 3 (three), as shown in FIG. 4B, the number "N" of division becomes 2 (two). Furthermore, as shown in FIG. **4**C, when there are 2 (two) wire rods in the range of the one wavelength, the number "N" of division is 1 (one).

The interval "K" between the neighboring wire rods becomes larger, as the number of the wire rods included in the range of the one wavelength becomes smaller. For example, in a case that the usable frequency for the patch antenna **12** is "100 [MHz]", and speed of light is "3×10^8 [m/s]", the wavelength "λ" is calculated by the "3×10^8 [m/s]"/"100 [MHz]". As a result, the wavelength "λ" becomes "3 [m]".

In the above explained structure, since the dielectric body **16** is provided between the bottom-board portion **14** and the horizontal feed-line portion **15**B (a portion of the feed-line portion **15**), a structure for a microstrip-transmission path is formed. Radio wave, which is transmitted or received via the radiation-element portion **13**, is sent from or sent to an electric circuit (not shown) via the structure for the microstrip-transmission path.

A relationship between the number "N" of division for the one wavelength and transmissivity "T" of sunlight through the patch antenna **12** will be explained with reference to FIG. **5**.

FIG. **5** shows an example of a case, according to which the material for the wire rod is cupper (ρ=58×10^6 [S/m]) and the usable frequency "f" is 100 [MHz]. The wire diameter "ϕ" for each characteristic curve indicated by a letter "a", "b" or "c" is larger than (or equal to) the epidermal depth "d". More exactly, the letter "a" shows a case in which the wire diameter "ϕ" for the wire rod is larger than the epidermal depth "d" by ten (10.0) times. The letter "b" shows a case in which the wire diameter "ϕ" for the wire rod is larger than the epidermal depth "d" by three (3.0) times. The letter "c" shows a case in which the wire diameter "ϕ" for the wire rod is larger than the epidermal depth "d" by one (1.0) times. A letter "d" shows a case in which the wire diameter "ϕ" for the wire rod is larger than the epidermal depth "d" by 0.3 times. In other words, it shows the case in which the wire diameter "ϕ" for the wire rod is smaller than the epidermal depth "d".

In FIG. **5**, a hatched area **Z1** indicates an area in which the wire diameter "ϕ" for the wire rod is smaller than the epidermal depth "d". A performance of the patch antenna **12** is extremely decreased in this area Z**1**. Another hatched area Z**2** indicates such an area, in which the number "N" of division for the one wavelength is smaller than "1". In other words, the number of the wire rods included in the range of the one wavelength becomes smaller than 2, so that the interval "K" between the wire rods becomes larger than the wavelength "λ". Therefore, the performance of the patch antenna **12** is also extremely decreased in this area Z**2**.

The transmissivity "T (%)" of sunlight indicates a degree of the sunlight passing through the patch antenna **12**, which can be obtained by the following formula 3:

$$T=((K-\phi)^2/K^2)\times100 \qquad \text{<Formula 3>}$$

As shown in FIG. **5**, in the case indicated by the letter "a", the interval "K" between the wire rods becomes sufficiently large, when the number "N" of the division for the one wavelength is smaller than 200, so that the transmissivity "T (%)" of sunlight becomes a value larger than 99 (%). In the case indicated by the letter "b", the interval "K" between the wire rods becomes sufficiently large, when the number "N" of the division for the one wavelength is smaller than 600, so that the transmissivity "T (%)" of sunlight becomes a value larger than 99 (%). In the case indicated by the letter "c", the interval "K" between the wire rods becomes sufficiently large, when the number "N" of the division for the one wavelength is smaller than 2000, so that the transmissivity "T (%)" of sunlight becomes a value larger than 99 (%).

In the case indicated by the letter "d", namely in the case that the wire diameter "ϕ" for the wire rod is smaller than the epidermal depth "d", the transmissivity "T (%)" of sunlight is expected to become a value larger than 99 (%), when the number "N" of the division for the one wavelength is smaller than 5000. However, since the case of the letter "d" is included in the area Z**1** (in which the wire diameter "ϕ" is smaller than the epidermal depth "d"), the performance of the patch antenna **12** is extremely decreased. Namely, the antenna **12** can not sufficiently bring out the function for the antenna.

According to the present embodiment, as explained above, the antenna integrated with the solar battery has the solar battery **11** and the patch antenna **12**, wherein the patch antenna **12** has the radiation-element portion **13** arranged above the solar battery **11**. The radiation-element portion **13** is made of metallic material, which is formed not in the thin film but in the net-like fashion by wire rods **13***a*. In the radiation-element portion **13** of such structure, resistivity is not increased too much, and thereby loss of the patch antenna **12** as a whole can be made smaller. Accordingly, the antenna gain can be improved.

In addition, the bottom-board portion **14**, which is arranged above the solar battery **11** and forms a part of the patch antenna **12**, is made of the metallic wire rods **14***a* in the net-like fashion. Furthermore, the feed-line portion **15**, which is also arranged above the solar battery **11** and forms a part of the patch antenna **12**, is made of the metallic wire rods **15***a* in the net-like fashion. The resistivity for the bottom-board portion **14** and the resistivity for the feed-line portion **15** are not increased. The loss of the patch antenna **12** is thereby made smaller as a whole to thereby further improve the gain for the patch antenna.

The radiation-element portion **13**, the bottom-board portion **14** and the feed-line portion **15** are arranged above the solar battery **11** and the wire rods **13***a*, **14***a* and **15***b* are arranged to overlap each other in the vertical direction. According to such a structure, those portions **13**, **14** and **15** do not largely block out the sunlight reaching to the solar battery **11**, so that the solar battery **11** can effectively and sufficiently receive the sunlight.

In addition, since the radiation-element portion **13**, the bottom-board portion **14** and the feed-line portion **15** are supported by the transparent dielectric body **16**, the transmissivity of the sunlight reaching to the solar battery **11** is not adversely affected. The radiation-element portion **13**, the bottom-board portion **14** and the feed-line portion **15** are stably and firmly supported by the dielectric body **16**.

The outer shape of the dielectric body **16** coincides with the outer shape of the solar battery **11** in the vertical direction. The upper side surface of the solar battery **11** is not directly exposed to the outside. In other words, the upper side surface of the solar battery **11** is protected by the antenna **12** arranged on the solar battery **11**.

In addition, the wire dimension "ϕ" for the respective wire rods **13***a*, **14***a* and **15***a* is made to be larger than the epidermal depth "d", which is obtained from the usable frequency "f" of the patch antenna **12**. The interval "K" between the neighboring wire rods **13***a*, **14***a* and **15***a* is made to be smaller than the wavelength "λ", which is also obtained from the usable frequency "f" of the patch antenna **12**. The performance of the patch antenna **12** is not decreased, so that the patch antenna **12** can effectively bring out its function.

The respective wire rods **13***a*, **14***a* and **15***a* are so arranged as to overlap the bus-bar electrodes ha and the grid lines **11***b* in the vertical direction. The wire rods **13***a*, **14***a* and **15***a* do not largely block out the sunlight reaching to the solar battery **11**. In other words, amount of the sunlight which is blocked out by the wire rods **13***a*, **14***a* and **15***a* can be minimized, so that the solar battery **11** can sufficiently receive the sunlight.

(Second Embodiment)

A second embodiment of the present disclosure will be explained with reference to FIGS. **6**A and **6**B. As shown in FIG. **6**A, an antenna **20** integrated with a solar battery has an inverse-F-type antenna **22** in place of the patch antenna **12**.

The inverse-F-type antenna **22** has a radiation-element portion **23** arranged on the upper side of the solar battery **11**. As shown in FIG. **6**B, the radiation-element portion **23** is made of fine metallic wire rods **23***a* and formed in a net-like fashion. The inverse-F-type antenna **22** has a bottom-board portion **24** arranged above the solar battery **11**. As shown in FIG. **6**B, the bottom-board portion **24** is likewise made of fine metallic wire rods **24***a* and formed in a net-like fashion. The inverse-F-type antenna **22** further has a feed-line portion **25** arranged above the solar battery **11** but below the bottom-board portion **24**. The feed-line portion **25** is likewise made of fine metallic wire rods (not shown) and formed in a net-like fashion. The feed-line portion **25** is composed of a vertical feed-line portion **25**A extending in the vertical direction and a horizontal feed-line portion **25**B extending in the horizontal direction. The inverse-F-type antenna **22** further has a connecting line portion **26** for connecting one end of the radiation-element portion **23** to the bottom-board portion **24**. Although not shown in the drawing, the connecting line portion **26** is likewise made of fine metallic wire rods and formed in a net-like fashion.

According to the second embodiment, the radiation-element portion **23** (which is a part of the inverse-F-type antenna **22**) is made of the fine metallic wire rods **23***a* and formed in the net-like fashion. Since resistivity of the radiation-element portion **23** is not increased too much, and thereby loss of the inverse-F-type antenna **22** as a whole can be made smaller. Accordingly, the antenna gain can be improved. In addition, since the bottom-board portion **24**, the feed-line portion **25** and the connecting line portion **26** (which are components for the inverse-F-type antenna **22**) are formed in the net-like fashion by the fine metallic wire rods, the loss of the inverse-F-type antenna **22** can be made smaller as a whole and thereby the antenna gain can be further improved.

(Third Embodiment)

A third embodiment of the present disclosure will be explained with reference to FIGS. **7**A and **7**B. As shown in FIG. **7**A, an antenna **30** integrated with a solar battery has a dipole antenna **32** in place of the patch antenna **12**.

The dipole antenna **32** has a pair of radiation-element portions **33**A and **33**B arranged above the upper side of the solar battery **11**. As shown in FIG. **7**B, each of the radiation-element portions **33**A and **33**B is made of fine metallic wire rods **33***a* and formed in a net-like fashion. The dipole antenna **32** has a bottom-board portion **34** arranged above the solar battery **11**. As shown in FIG. **7**B, the bottom-board portion **34** is likewise made of fine, metallic wire rods **34***a* and formed in a net-like fashion. The dipole antenna **32** further has a feed-line portion **35** arranged above the solar battery **11** but below the bottom-board portion **34**. The feed-line portion **35** is likewise made of fine metallic wire rods (not shown) and formed in a net-like fashion. The feed-line portion **35** is composed of a vertical feed-line portion **35**A extending in the vertical direction and a horizontal feed-line portion **35**B extending in the horizontal direction. The dipole antenna **32** further has a connecting line portion **36** for connecting one end of the radiation-element portion **33**B to the bottom-board portion **34**. Although not shown in the drawing, the connecting line portion **36** is likewise made of fine metallic wire rods and formed in a net-like fashion.

As in the same manner to the first and second embodiment, the radiation-element portions **33**A and **33**B (which are parts of the dipole antenna **32**) are made of the fine metallic wire rods **33***a* and formed in the net-like fashion in the third embodiment. Since resistivity of the radiation-element portions **33**A and **33**B is not increased too much, and thereby loss of the dipole antenna **32** as a whole can be made smaller. In addition, since the bottom-board portion **34**, the feed-line portion **35** and the connecting line portion **36** (which are components for the dipole antenna **32**) are formed in the net-like fashion by the fine metallic wire rods, the loss of the dipole antenna **32** can be made smaller as a whole and thereby the antenna gain can be further improved.

(Further Embodiments and/or Modifications)

The present disclosure should not be limited to the above embodiments but can be modified in various ways without departing from the spirit of the present disclosure. For example, the following modifications can be made.

The bottom-board portion and the feed-line portion may be formed not above the solar battery but below the solar battery. For example, FIGS. **8**A and **8**B show a modification of the first embodiment, according to which the bottom-board portion **14** and the horizontal feed-line portion **15**B (a part of the feed-line portion **15**) are arranged below the solar battery **11**. FIGS. **9**A and **913** show a modification of the second embodiment, according to which the bottom-board portion **24** and the horizontal feed-line portion **25**B (a part of the feed-line portion **25**) are arranged below the solar battery **11**. FIGS. **10**A and **10**B show a modification of the third embodiment, according to which the bottom-board portion **34** and the horizontal feed-line portion **35**B (a part of the feed-line portion **35**) are arranged below the solar battery **11**. According to the above modifications, only the radiation-element(s) **13**, **23**, **33**A and **33**B of the respective antennas **12**, **22** and **32** are arranged above the solar battery **11**. The amount of the sunlight, which will be blocked out by the components of the antenna, can be further reduced, to thereby increase the amount of the sunlight to be received by the solar battery **11**.

According to the present disclosure, the components for the antenna are made of multiple fine wire rods and formed in the net-like fashion. The antenna can be easily, formed in any desired shape, so as to bring out an appropriate antenna performance.

The above embodiments and modifications can be combined to each other in the present disclosure.

What is claimed is:

1. An antenna integrated with a solar battery comprising:

the solar battery;

an antenna having a radiation-element portion arranged above an upper side of the solar battery;

a bottom-board portion arranged between the radiation-element portion and the solar battery in the vertical direction of the antenna; and

a feed-line portion having a vertical feed-line portion and a horizontal feed-line portion, the horizontal feed-line portion being arranged between the bottom-board portion and the solar battery in the vertical direction of the antenna; wherein

the radiation-element portion is made of metallic wire rods and formed in a net-like fashion;

the wire rods are arranged to overlap an area for bus-bar electrodes and grid lines of the solar battery in a vertical direction of the antenna;

each of the wire rods is arranged parallel to the bus-bar electrodes or the grid lines when viewed in the vertical direction of the antenna;

the bottom-board portion is made of metallic wire rods and formed in a net-like fashion,

each of the wire rods of the bottom-board portion is arranged parallel to the bus-bar electrodes or the grid lines when viewed in the vertical direction of the antenna;

the horizontal feed-line portion of the feed-line portion is made of metallic wire rods and formed in a net-like fashion, and

each of the wire rods of the horizontal feed-line portion is arranged parallel to the bus-bar electrodes or the grid lines when viewed in the vertical direction of the antenna.

2. The antenna according to claim **1**, wherein

the wire rods for the radiation-element portion and the wire rods for the bottom-board portion overlap each other in the vertical direction of the antenna.

3. The antenna according to claim **1**, wherein

the wire rods for the radiation-element portion, the wire rods for the bottom-board portion and the wire rods for the horizontal feed-line portion overlap one another in the vertical direction of the antenna.

4. The antenna according to claim **1**, wherein

the radiation-element portion and the bottom-board portion are supported by a transparent dielectric body.

5. The antenna according to claim **4**, wherein

the dielectric body has an outer shape, which coincides with that of the solar battery in a vertical direction of the antenna.

6. The antenna according to claim **1**, wherein

the radiation-element portion, the bottom-board portion and the feed-line portion are supported by a transparent dielectric body.

7. The antenna according to claim **1**, wherein

a wire diameter of the wire rods is made to be larger than an epidermal depth of the wire rods at a usable frequency for the antenna.

8. The antenna according to claim **1**, wherein

an interval between the wire rods is made to be smaller than a wavelength of a usable frequency for the antenna.

9. The antenna according to claim **1**, wherein each of the wire rods is arranged parallel to both the bus-bar electrodes and the grid lines when viewed in the vertical direction of the antenna.

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